

Measuring and Modeling the Detection Limits in High Contrast Coronagraphic Images

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The achievable contrast (dynamic range) in coronagraphic high contrast images, is a critical parameter which determines the physical parameter space for faint companion detection (mass, separation). On the ground, the scientific goals are essentially the detection and study of giant planets. With Extreme Adaptive Optics and Coronagraphy, the current on-sky limitations are due to residual quasi-static speckles, which are not easily calibrated and are the dominant noise contribution. Future ground-based instruments (Gemini Planet Imager, VLT-Sphere) will include active calibration systems (speckle nulling) and spectrographs (Integral Field Units) to help push the dynamic range further. In space, although the problem is very different and the goals more ambitious (TPF), the dynamic range of a coronagraphic instrument will also be mainly limited by hard-to-calibrate, slow-varying speckles. Similar calibration approaches (active or passive) will be required to reach the detection of terrestrial planets. Theoretical statistical models of the noise can help us understand the properties of the residual speckles in such high contrast images. Models have now been developed and verified on real data to include the effects of static, quasi-static and residual atmospheric wavefront errors. Because of the generality of the physics involved, these models can be applied to both for ground-based or space-based instruments, depending on their parameters. In the case of actual coronagraphic images, like those obtained with the Lyot Project coronagraph, understanding of the detection limits is necessary to set upper-mass limits for non-detections and understand the performance of the instrument for further improvement. Detection limits and upper-masses of Vega's hypothetical companion are discussed.